1.3 Impact of Acid Deposition on Ecosystems

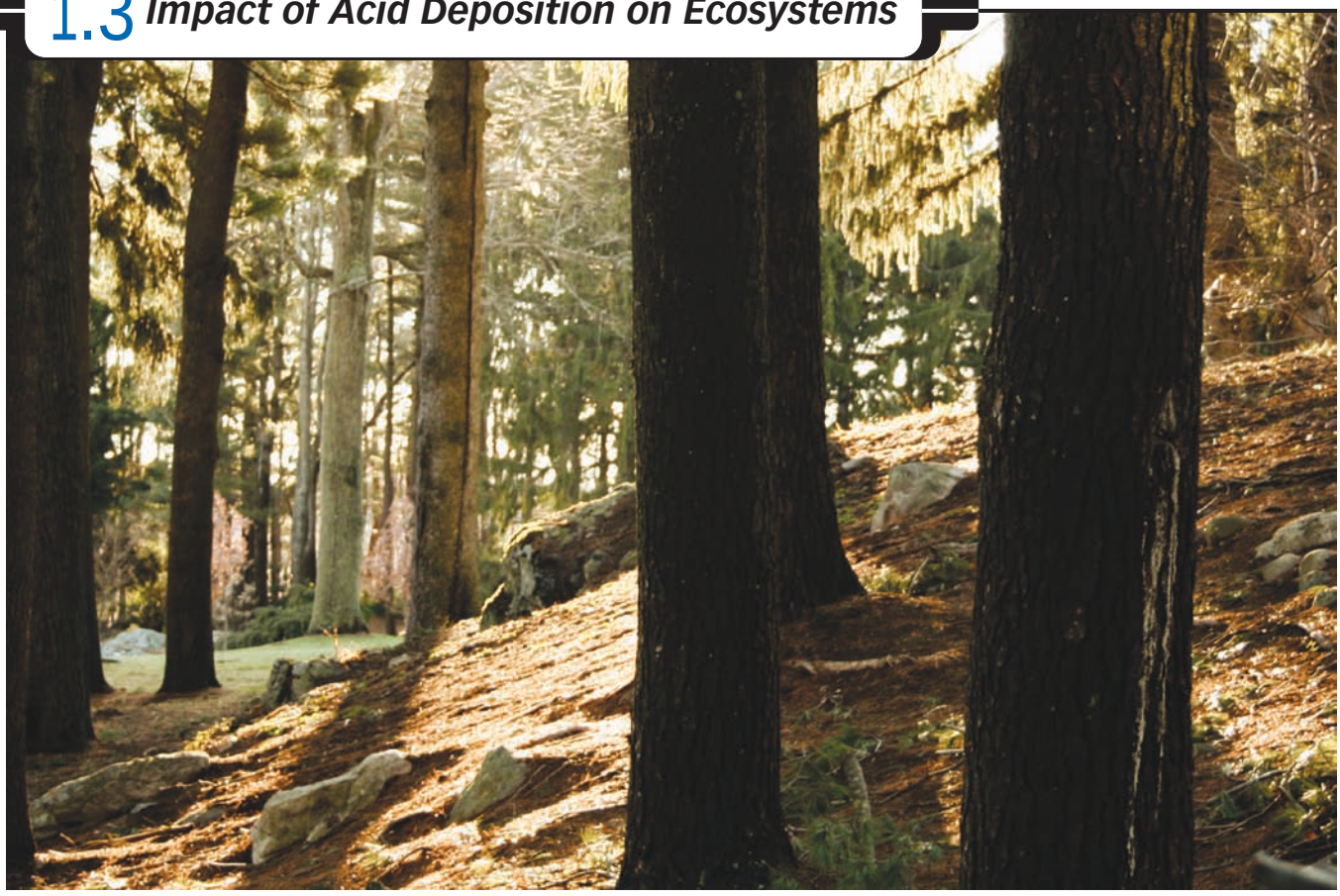


Figure B1.26: Data collection is an important process toward developing an understanding of the interactions of substances within ecosystems.

The study of environmental chemistry involves more than just the detection of substances. Scientists who study the environment conduct investigations to determine whether there is evidence of change in the environment. The area of the forest shown in Figure B1.26 has very little vegetation on the ground. Is there a connection between the dropped needles covering the forest floor and the amount of plant growth beneath these trees? Is the lack of plant growth related to the soil pH? Studies performed by environmental scientists in the field are a critical link toward understanding the changes that occur in ecosystems versus those that might be predicted.

Figure B1.27: Some mushroom species and some plant species can grow in the soil directly underneath pine trees.

Predictions currently being made by scientists rely upon the knowledge that comes from careful study of interactions within the environment. As many scientists will tell you, the complexity of interactions within an ecosystem makes the current level of understanding limited. Since the environment is the one thing that all organisms share, research is necessary to understand its ability to cope with stress from pollution.

In this lesson you will expand your knowledge of the complexity of ecosystems and the chemical interactions that can occur. Before you continue, however, do you have a hypothesis that describes the relationship between the presence of emissions in the environment and their effects? What kinds of experiments would you need to conduct to test and support your hypothesis? Do you have an idea of what you might expect to observe?

Given all that you have learned about the ability of some substances within emissions to react with water, does a relationship exist between the presence of these substances in water and the water's acidity? In a previous investigation, the emissions from burning coal acidified water. Do similar reactions occur in nature? In the next investigation you will have the opportunity to analyze data and gain further insight into this question.

Utilizing Technology

Testing a Hypothesis

Purpose

You will investigate the relationship between the presence of substances in rainwater and the pH of rainwater.

Science Skills

- ✓ Analyzing and Interpreting
- ✓ Communication and Teamwork

Background Information

In previous courses you described the relationship between two variables as a **direct variation**, an **inverse variation**, or having **no relationship**. In this investigation you will analyze the data collected from rainwater and determine which type of relationship is demonstrated. The data provided are from rainfall monitoring sites throughout Alberta. Included in the data are information about the quantity of rainfall, pH, total acidity of rainfall, and the nitrate and sulfate concentrations. Each of these headings is considered to be a variable—information that was measured and recorded during this study.

- **direct variation:** a relationship between two related variables where an increase in the magnitude of one variable results in an increase in the magnitude of the related variable
- **inverse variation:** a relationship between two related variables where an increase in the magnitude of one variable results in a decrease in the magnitude of the related variable
- **no relationship:** a situation where no recognizable pattern is demonstrated between two variables

Pre-Lab Questions

1. Identify a relationship between two of the variables (sets of information) listed in the background information.
2. Describe the relationship—direct variation, inverse variation, or no relationship—you feel exists between the two variables defined in question 1. Explain why you chose this relationship.
3. Predict what you think the trends within the data for these two variables will show.
4. Repeat questions 1 to 3 for other combinations of variables you feel will demonstrate a direct variation, an inverse variation, or no relationship.

Materials

- computer with a spreadsheet program (e.g., Excel)
- printer

Procedure

Open the "Rainfall Data" spreadsheet on the Science 30 Textbook CD. Check with your teacher for directions about how many areas within this spreadsheet you will be analyzing. Complete the following steps for each set of data you analyze.

step 1: Identify the headings listed in the background information as they appear on the spreadsheet.

step 2: Graph two or more variables shown in the data. Use appropriate titles and axes labels. Then save your graph.

step 3: Repeat step 2 for other data you may want to investigate or for other areas your teacher instructs you to analyze. Save any additional graphs.

step 4: On each graph, use a text box to insert the hypothesis between the variables graphed.

step 5: Describe any trends on each graph. Add labels and descriptive text to your graphs that indicate these regions.

step 6: On each graph, write an explanation of how the trends or patterns demonstrated by the data support or do not support the hypothesis.

step 7: Create a new document that includes each of the graphs analyzed. At the front of this document, create a summary table that lists the variables that were compared and the relationships identified. Ensure that the order in which the graphs appear is logical and easy to reference from the summary table.

step 8: Below the summary table described in step 7, write a brief commentary indicating whether the relationships between variables you investigated were consistent with the relationships you predicted earlier. Indicate how these relationships are consistent with or differ from what you know about acid deposition.

step 9: Print a copy of the document containing the summary table, commentary on trends and relationships between variables, and the annotated graphs you prepared during your analysis.

Wind Patterns

The "Testing a Hypothesis" investigation provided an opportunity for you to use data to test a hypothesis you developed. As you may have expected, higher levels of sulfates and nitrates in rainwater result in a higher concentration of hydronium ions in the water (direct variation) and, thus, results in a lower pH (inverse variation). These types of relationships are consistent with what is known about the effect of natural and human-made sources of emissions and their respective roles in the production of acid rain.

As mentioned earlier, many other factors can have an influence within an environmental system. One of these factors is wind. Weather in Alberta can be quite variable. There is a saying, "If you don't like the weather in Alberta, wait five minutes." One day it is excessively hot; the next day you are sure it is going to snow. In the next activity you will look at a major feature of the weather patterns across North America. As you complete this activity, remember to consider what influences weather patterns might have on acid deposition.

Utilizing Technology

Prevailing Wind Patterns

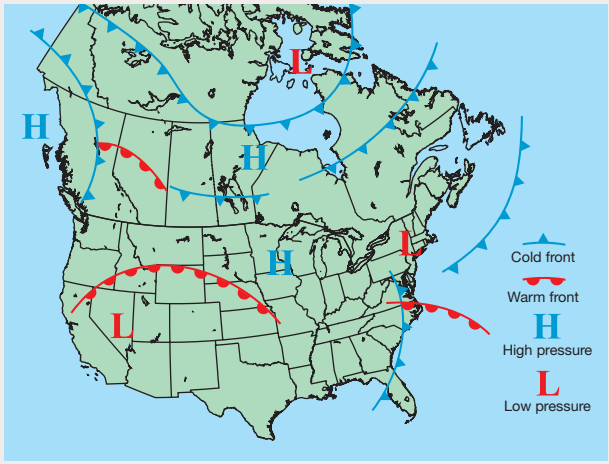


Figure B1.28: Precipitation and wind are weather patterns that influence acid deposition.

Purpose

You will examine the prevailing wind patterns in Alberta and in Canada.

Background Information

Have you completed a field study where you measured wind speed and direction? Wind is an abiotic factor of an ecosystem. Wind enables the movement of matter, whether it is water vapour in clouds, solid matter eroded by winds, or gases within atmospheric currents. The jet stream is the most influential wind current in North America. In this activity you will be asked to locate, download, and assemble information about wind patterns. The maps you create in this activity will be used in other activities within this lesson to further investigate issues related to acid deposition.

Materials

- computer with Internet connection
- handouts from the Science 30 Textbook CD
  - "Map of Canada and the US"
  - "Map of Alberta" (2 copies)

Science Skills

✓ Analyzing and Interpreting

Procedure

Part A: Map of Canada and the US

step 1: Search the Internet for images of daily, monthly, and seasonal patterns of the jet stream.

step 2: Draw a line representing an approximate average location for the jet stream across North America.

step 3: Determine the direction of the winds in areas north and south of the jet stream. Use vector arrows to indicate the direction of the winds on your map.

Part B: Map of Alberta

step 1: Search the Internet for images of daily, monthly, and seasonal wind patterns in Alberta.

step 2: Use vector arrows to indicate the direction of the winds in Alberta. **Note:** If you notice there is a change in the direction of wind patterns in the province during different seasons, use additional maps to identify these patterns. Ensure that all maps are properly labelled.

Analysis

1. Define the term *jet stream*. State the general direction of the jet stream.
2. Explain the effect the jet stream has on weather and climate in western Canada.
3. Comment on the statement, "Wind patterns in Canada and Alberta are always the same."
4. From your analysis of wind patterns, does Canada's position in the northern hemisphere ensure that air transported by currents, such as the jet stream, are relatively clean and unpolluted?

The Jet Stream and Acid Deposition

Wind patterns like the jet stream provide a way for acid deposition to be transported. As you will see later, acid deposition can be transported short and long distances. The predictability of wind patterns provides a way to trace the path of acid deposition back to its source. What happens to an ecosystem when acid deposition settles? How would it affect the plants, soil, and water it touches? Maybe the next activity will help you answer these questions.

Investigation

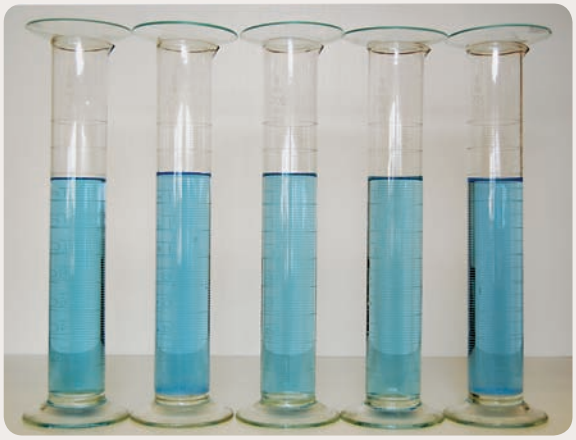
Acid Deposition and Its Effect on Simulated Lake Water—Demonstration

CAUTION!

This demonstration should be performed only by your teacher. Avoid exposure to sulfur dioxide. Do not handle any of the solutions used in this demonstration.

Purpose

You will see a demonstration of the effect of acid deposition on simulated lake water.



Materials

- 5 large graduated cylinders
- simulated lake water
- bromocresol green indicator
- calcium carbonate, $CaCO_3(s)$
- spray bottle containing water
- sulfur dioxide (prepared prior to demonstration)
- stopwatch

Experimental Design

Samples of simulated lake water will be placed into each cylinder. A small piece of calcium carbonate will be added to two of the cylinders. To test the cylinders, sulfur dioxide gas will be added. A spray bottle of water will be used with some of the cylinders to simulate precipitation. All cylinders will be monitored for changes that occur and the length of time over which the changes occur.

Science Skills

- ✓ Performing and Recording
- ✓ Analyzing and Interpreting

Data Collection

step 1: Construct a data table with the headings Cylinder, Initial Colour of Contents, $SO_2(g)$ Added, Water Spray Added, $CaCO_3(s)$ Added, and Relative Time for Colour Change.

step 2: Observe the colours of the contents of each cylinder before adding the $SO_2(g)$. Record each colour in your table.

step 3: Record which cylinders had $SO_2(g)$ added, which had $CaCO_3(s)$ added, and which received water spray.

step 4: To simulate the mixing effect made by waves and by water currents, swirl the contents of each flask once during each 10-min interval. Observe changes to colour and other aspects over the next 50 min. Record any changes that occur over each 10-min interval.

Analysis

1. Earlier, you discovered the importance of experimental controls. Identify the cylinders that were experimental controls. Briefly describe their purpose. In some experiments, only one control is used. Why are two control cylinders used in this experiment?
2. Identify the samples of simulated lake water that were exposed to wet acid deposition, that were exposed to dry acid deposition, and that were not exposed to acid deposition.
3. Describe the effect that $CaCO_3(s)$ had on the simulated lake-water samples. Support your answer using the evidence collected during the experiments and, if possible, a balanced chemical equation.
4. This demonstration was designed to simulate conditions that could occur in nature. List natural sources of $CaCO_3(s)$. Explain how $CaCO_3(s)$ could come into contact with lake water to form a chemical system.

Effects of Acid Deposition on the Environment and Ecosystems

Acid deposition can affect the pH of water. The hydronium ions formed during the chemical reaction between acids and water not only act to lower the pH of a body of water, but can react with other substances in the system. Carbonate ions, $CO_3^{2-}(aq)$, are a naturally occurring base present in many bodies of water and in the soil. In Alberta, the pH of most lakes is above 7 and can be as high as 8.3. The slightly **alkaline** pH of the lake water is due to the presence of dissociated carbonate ions that enter the water from dissolving **minerals**, such as calcium carbonate and magnesium carbonate present in limestone.

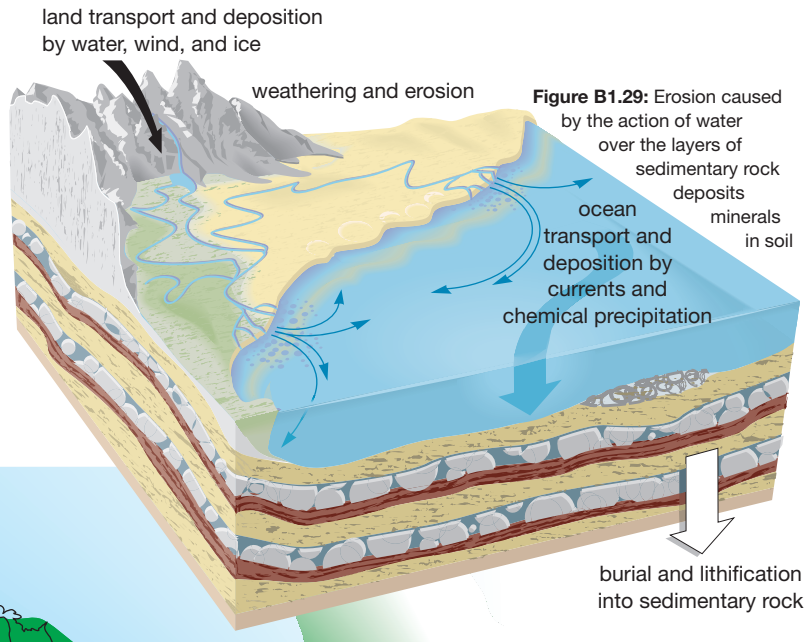


Figure B1.29: Erosion caused by the action of water over the layers of sedimentary rock deposits

- **alkaline:** having the properties of a base
- **mineral:** a solid, inorganic chemical compound produced by natural chemical processes

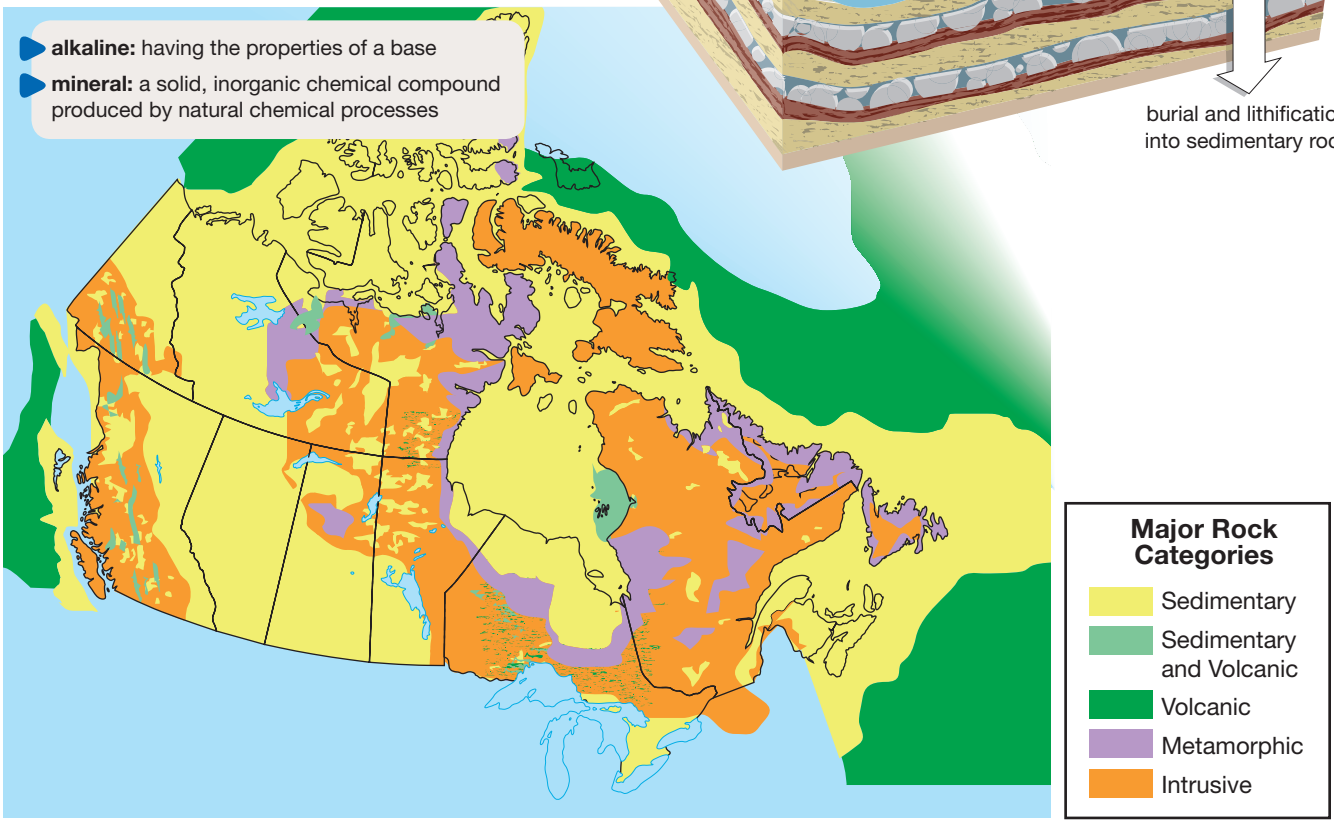
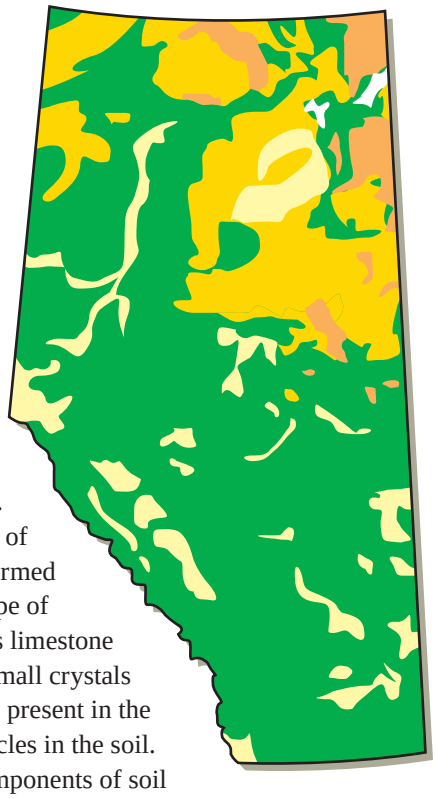


Figure B1.30: Geological events have resulted in a variety of rock types in Canada.

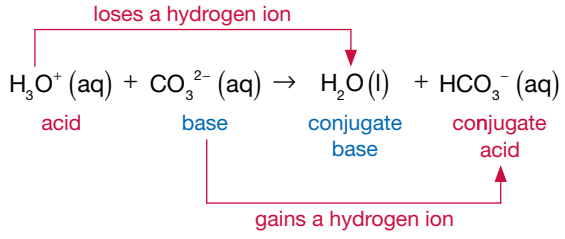
Figure B1.31: Soil contains small particles (a component of which is shown in this magnified sample) of eroded rocks from layers of exposed sedimentary rock. The chemical composition of the rock within a region influences the sensitivity of soil and lakes to acid deposition.

The area now called Alberta has undergone many geological changes. Many times throughout its history, Alberta has been covered by water. The coral reefs that developed at the bottom of these oceans were made up of calcium carbonate, $CaCO_3(s)$. Over time, the layers of calcium carbonate formed into limestone—a type of sedimentary rock. As limestone undergoes erosion, small crystals of calcium carbonate present in the limestone form particles in the soil.



The chemical components of soil have a great impact on its sensitivity to acid deposition. In the acid deposition demonstration earlier, the acid deposited into some of the cylinders containing simulated lake water was neutralized. Recall that the reaction between hydronium ions and carbonate ions involves the transfer of a hydrogen ion. The carbonate ions, acting as acceptors for hydrogen ions, convert hydronium ions into water molecules, thereby neutralizing the acid.

Reaction of Hydronium Ion and Carbonate Ion



Only a small percentage of soils in Canada have a high potential for neutralizing acid deposition. Much of the soil within the province of Alberta has a high potential, mainly due to the presence of carbonate.

Practice

Obtain a copy of the handouts "Potential of Soils and Bedrock to Reduce Acidity" and "Major Rock Categories" from the Science 30 Textbook CD. Use these maps to answer questions 29 to 36. In developing your answers, consult both maps and look for similarities, differences, and correlations.

29. Do all areas of Canada have similarities in their ability to neutralize acid deposition?

30. Indicate regions in Canada that have the highest potential to reduce acid deposition.

31. Do all of the areas with the highest potential to reduce acid deposition have a similar rock type? If so, identify it.

32. Indicate regions in Canada with the least ability to reduce acid deposition.

33. Do all of the areas with the lowest potential to reduce acid deposition have similar rock types? If so, identify the types of rock found in these regions.

34. Do all regions of Alberta have equal potential to reduce acid deposition? Support your answer.

35. Predict the effect of acid deposition on the pH of soil and the pH of lake water in Canada. Do you expect the pH values to increase, decrease, or remain constant? Explain why there may be more than one answer.

36. Within the map depicting the potential of soils to reduce the acidity from the atmosphere, there is a table describing aquatic sensitivity by province. Use this information to answer questions 36.a. to 36.d. **Note:** Zooming in on this table on your computer monitor will provide a clear view of the information.

a. Identify the province with the largest percentage of lakes with a high sensitivity to acid deposition.

b. Identify the province with the lowest percentage of lakes with a high sensitivity to acid deposition.

c. Is there a correlation between the sensitivity of lakes to acid deposition and the sensitivity to soil within a province? Explain whether there is a direct variation, indirect variation, or no relationship between the sensitivity of lakes and soils to acid deposition.

d. Hypothesize a reason for the relationship you identified in question 36.c.

Buffering and Buffering Capacity

The neutralization of acid deposition by bases, such as calcium carbonate—whether present in the soil, bedrock, or lake water—prevents the accumulation of hydronium ions. An increase in the concentration of hydronium ions makes a solution more acidic and lowers the solution's pH. As you will soon see, pH is an important factor that contributes to the viability of ecosystems; and changes in pH can have drastic effects on the survival of many organisms. The neutralization of acids by bases that prevents any change to the pH of soil or lake water is called **buffering**.

- **buffering:** a chemical reaction to minimize a change to the hydronium-ion concentration in soil or water
- **buffering capacity:** the relative ability of a substance to resist change to its pH despite the addition of an acid or base

As you may expect, some areas exposed to acid rain for longer periods of time eventually develop soil or surface water with lower pH values. In these situations, the accumulation of hydronium ions is due to an absence of basic substances within the soil or water. **Buffering capacity** is a measure of the amount of acid that can be neutralized by soil or surface water. In the acid deposition demonstration you observed earlier, which samples of lake water had the highest buffering capacity? If you look back at "The Potential of Soils and Bedrock to Reduce the Acidity of Atmospheric Deposition" map, can you predict which regions have higher, moderate, and lower buffering capacities?

Response of Plants to pH

Plants respond to the level of acidity in a variety of ways. The area directly underneath conifers is often lacking any other plant growth. As needles fall from pine and spruce trees to the ground, acids from the needles are transferred to the soil. This results in acidification of the soil. Few species of plants can tolerate the low pH of the soil immediately underneath these trees. Similarly, crop plants used in agriculture have limited tolerance for variation in pH. Therefore, it is important for farmers to select crops best suited to the pH of the soil. Soil exposed to acid deposition or to certain crops can become acidified and, as you will learn later, must be properly managed to remain fertile.

AGRICULTURAL PLANTS AND SOIL pH FOR OPTIMAL GROWTH

Plant	Soil pH for Optimal Growth
alfalfa	6.5 to 7.0
barley	6.3 to 6.5
blueberries	4.5
canola	5.5 to 8.3
clover	5.8 to 6.2
corn	5.8 to 6.2
oats	5.8 to 6.2
pasture grass	5.5 to 6.2
sugar beets	6.5 to 8.0
potatoes	5.2 to 8.0
wheat	5.5 to 6.5

DID YOU KNOW?

The dark patches on this potato are potato scabs, the result of an infection by bacteria that live in the soil. Although the infection does not affect the taste of the potato, farmers often choose to plant potatoes in soils with a pH below 5.3 to prevent the development of potato scabs. The bacteria cannot tolerate a pH this low.

DID YOU KNOW?

Canola is a variety of the rapeseed plant. Canola was developed by selective plant breeding technologies to produce an oil with specific properties.

Plant Nutrients, Metal Leaching, and pH

Reactions between acids and minerals in the soil are important to the cycling of matter as described in **biogeochemical cycles**. In previous science courses you examined cycles that describe the conversions of carbon, oxygen, nitrogen, and water in the environment. Reactions involving other elements are of equal importance to environmental scientists. Calcium ions, $Ca^{2+}(aq)$, are one of the required nutrients for plant growth. The reaction of $CaCO_3(s)$ that neutralizes acids present in rainfall is one manner in which calcium ions—normally bound to carbonate and other ions—become available to plants.

Other nutrients are listed in Figure B1.32, along with their function. One of these functions is the production of chlorophyl—the molecule essential for photosynthesis and for influencing a plant's growth or reproduction.

biogeochemical cycle: a diagram representing the movement of elements and compounds between living and non-living components of an ecosystem

REQUIRED PLANT NUTRIENTS

Type	Element	Forms Used by Plants	Function
macronutrients (essential nutrients needed in large quantities)	calcium	Ca^{2+}	• important for root growth • component of cell walls
	magnesium	Mg^{2+}	• essential for chlorophyl formation
	nitrogen	NH_4^+, NO_3^-	• essential for proper leaf and stem growth • protein synthesis
	phosphorus	PO_4^{3-}, HPO_4^{2-}, $H_2PO_4^-$	• important for germination and growth of seeds, root growth, flower, and fruit production
	potassium	K^+	• promotes quick growth and disease resistance
micronutrients (essential elements needed in small quantities)	boron	BO_3^{3-}, $B_4O_7^{2-}$	• required for transporting matter within plant and for reproduction
	chlorine	Cl^-	• may affect use and production of sugars by plant
	copper	Cu^+, Cu^{2+}	• important in plant reproduction
	iron	Fe^{2+}	• required for the production of chlorophyl and oxygen
	manganese	Mn^{2+}	• required in reactions to make sugars and chlorophyl
	molybdenum	MoO_4^{2-}	• required for reactions that convert nitrogen in the atmosphere into forms that plants can use
	zinc	Zn^{2+}	• required for protein synthesis and reactions involving sugars

Figure B1.32: Some plant nutrients may take a variety of forms; but each nutrient is involved in an important role in plant growth, function, or reproduction.

Plants absorb nutrients from the soil through their roots. Prior to planting, farmers may conduct a soil analysis to determine the mineral and nutrient content of the soil. Plants have an optimal pH for growth. In addition to pH, many plants also have specific nutrient requirements.

Figure B1.33: The yellow leaves of the soybean plant in this photo are the result of chlorosis—nutrient deficiencies in the soil.

Acid deposition can present another problem that complicates the ability to grow plants or crops. Nutrients must be in a form that allows them to be absorbed through the roots of plants.

A change in soil pH can result in the formation of insoluble forms of these nutrients, making them unattainable by roots. Chlorosis—the yellowing of plant leaves due to a lack of chlorophyl—is caused by nutrient deficiencies in soil. The yellow appearance of plant leaves is one indicator that a plant may have been exposed to acid deposition. As shown in Figure B1.34, the availability of nutrients is affected by pH. Can you identify a general trend regarding the availability of the nutrients over the pH range shown?

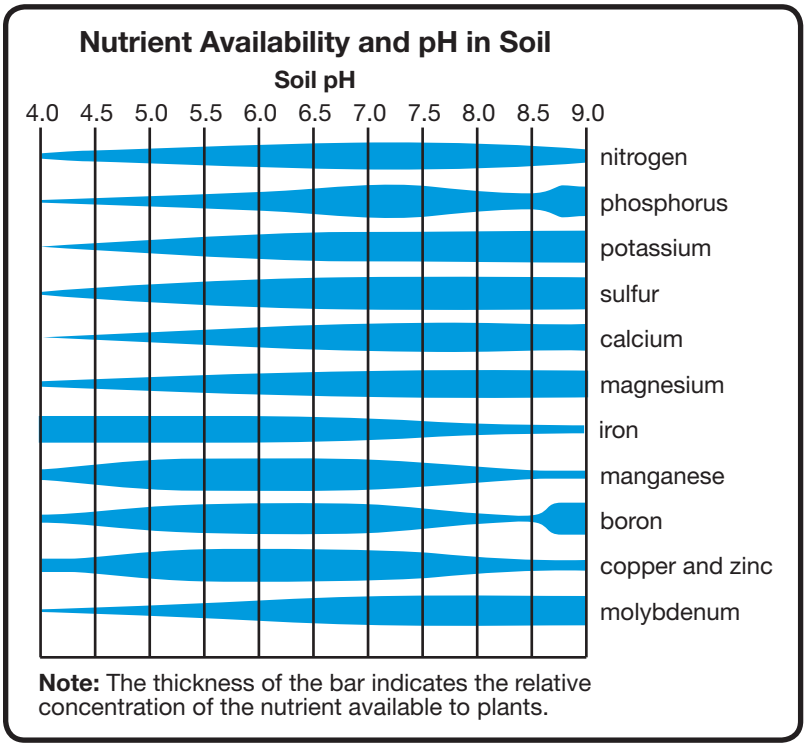


Figure B1.34: Soil pH influences the availability of nutrients. The thickness of the bars indicates where soil concentrations of each nutrient (in forms that plants can absorb) are highest and lowest.

The addition of acids to the soil can make metal ions, like Ca^{2+} and Mg^{2+}, available to plants. Hydronium ions present in soil, as a result of prolonged acid deposition, can react with other compounds in the soil. One effect of prolonged acid deposition is the **leaching** of aluminium ions, $Al^{3+}(aq)$, and mercury(II) ions, $Hg^{2+}(aq)$.

leaching: extracting a substance from a solid by dissolving it in a liquid; the removal of metal ions from topsoil that allows for their movement into lower levels of soil or into surface water

Within soil, aluminium ions are normally bound to hydroxide ions as aluminium hydroxide, $Al(OH)_3(s)$. Since aluminium hydroxide does not dissolve in water easily, very little dissociation occurs. This keeps the concentration of aluminium ions in the soil very low. When exposed to acids, the chemical reaction between aluminium hydroxide and hydronium ions allows aluminium ions to exist as dissociated ions in the soil. Unless precipitated by a reaction with another substance in the soil, the concentration of aluminium ions will accumulate over time. Higher concentrations of aluminium ions can affect plants and soil in many ways, including

- decreasing the growth of roots
- preventing the absorption of calcium
- reducing the population of soil bacteria involved in the decomposition of dead plant matter

Higher concentrations of aluminium ions in lakes and streams are toxic to fish. Exposure to aluminium ions has been known to damage the gills of older fish and increase the number of deaths of young fish.

Mercury is another metal found in soil, but in very small amounts. In acidic soils, a reaction between hydronium ions and compounds containing mercury can occur, resulting in the leaching of mercury(II) ions, $Hg^{2+}(aq)$. Once in the water or in the soil, micro-organisms convert mercury(II) ions into methyl mercury—a substance that is rapidly absorbed by other organisms. Mercury has no real function in living things and cannot be excreted. Since it is not removed, mercury tends to accumulate within cells and tissues of exposed organisms over their lifetime, often to levels that can be toxic to the organism itself and to any other organism that consumes it.

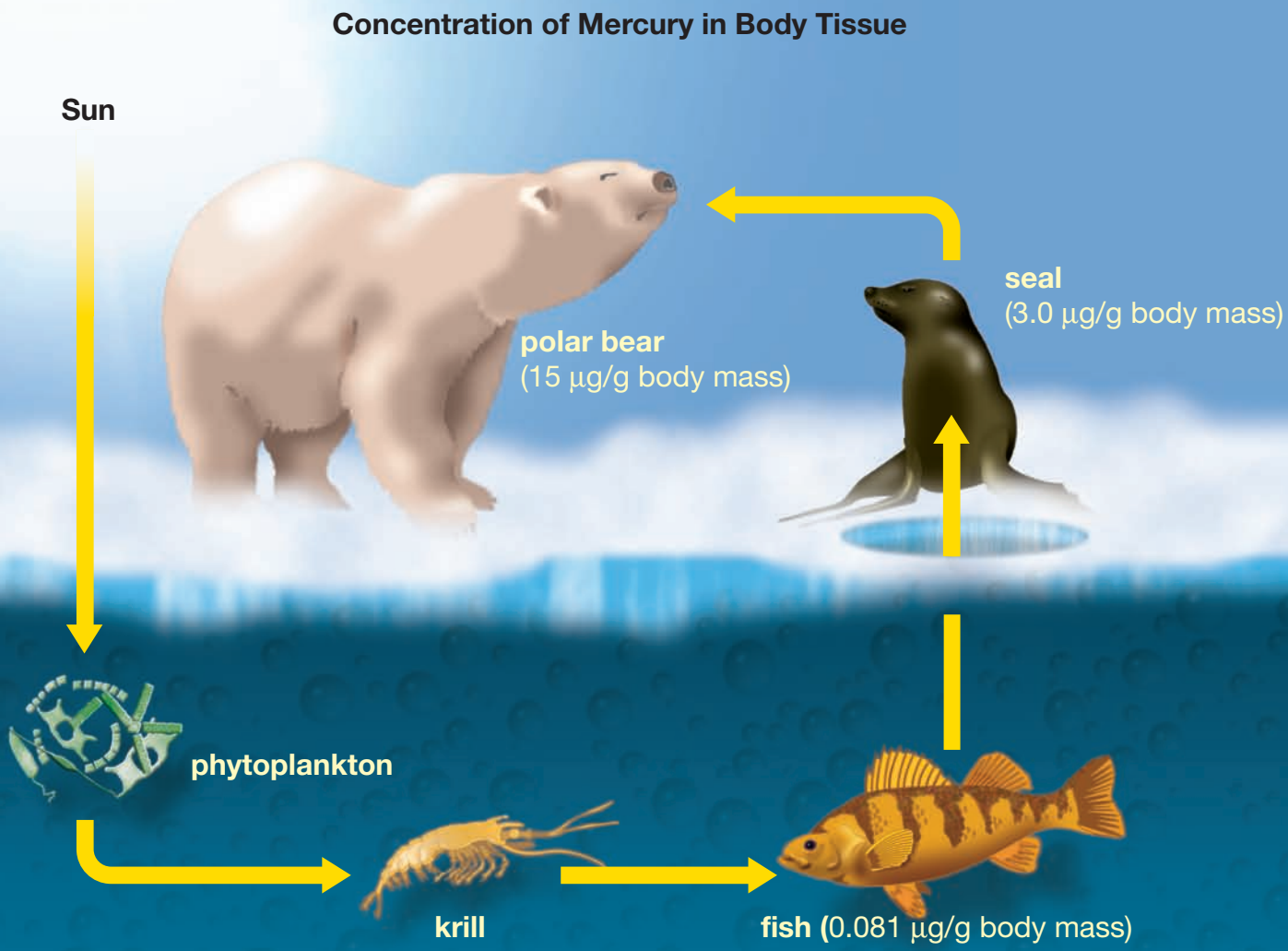


Figure B1.35: The transfer of energy within a food chain can also be used to demonstrate biomagnification of mercury.

Biomagnification can occur with a variety of substances. Regardless of the substance, bioaccumulation occurs because of the inability of an organism to use or eliminate the substance. In a situation where biomagnification occurs, the concentration of mercury within the body of each organism is higher than the concentration of mercury in its environment. Also, as you compare the concentration of mercury at each successive level of the food chain, you will see that there is a significantly higher concentration in the tissues of a predator than in its prey. Can you estimate the magnitude of the change?

Mercury poisoning occurs when the concentration of mercury within an organism reaches a toxic level. In many ecosystems, an organism suffering from mercury poisoning tends to be high up in the food chain. Where do humans fit in a food chain? Do you think information about the bioaccumulation of mercury in food chains would be useful to Aboriginal communities, many of whom have retained their traditional diets?

Acid deposition can cause other metals to have toxic effects on an ecosystem through leaching. These metals include lead, zinc, copper, cadmium, chromium, manganese, and vanadium.

biomagnification: the tendency of a pollutant to appear at higher concentrations at higher levels in a food chain

Expressing Concentration

In environmental science, the concentration of a substance is expressed in many ways. You have seen that hydrogen-ion concentration can be expressed as mol/L or as pH. Because the concentrations of substances that bioaccumulate are very low, units like μg/g of body mass, parts per million, parts per billion, and even parts per trillion are used. The formula to calculate parts per million is in the Science Data Booklet. You can adapt this formula to parts per billion by replacing 10^6 with 10^9 or to parts per trillion by replacing 10^6 with 10^{12}.

Practice

37. The plant in this photograph was grown in soil with a pH of 5.5.

a. State the name that describes the yellowing of the plant leaves.

b. Explain why the plant leaves are yellowing.

c. Indicate a possible cause for the condition of the plant.

d. Explain the relationship between soil pH and the yellowing of the plant leaves.

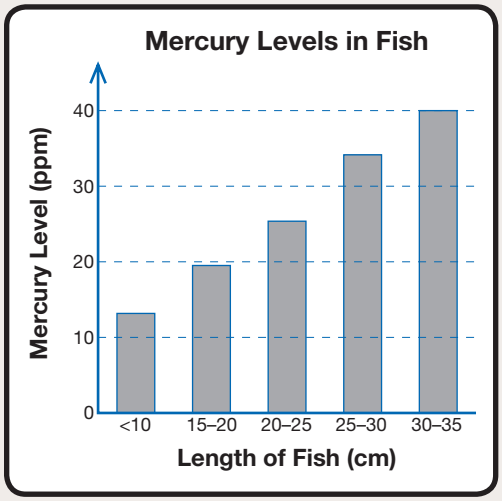
38. The term *biomagnification* refers to the progressive buildup of heavy metals (or other substances) in successive levels of a food chain. Use the concentrations of mercury in Figure B1.35 (on page 197) to calculate ratios of the concentration of mercury in a seal and a polar bear relative to their prey. Explain how the ratios you calculated demonstrate that bioaccumulation is occurring.

39. Use the information in Figure B1.35 to calculate concentration levels of mercury in other organisms in the arctic food chain.

a. Fish concentrate mercury to a level 500 times greater than the concentration of mercury in the krill they consume. Calculate the approximate concentration of mercury in krill.

b. The concentration of mercury in krill is 1000 times greater than that of phytoplankton. Calculate the concentration of mercury in phytoplankton.

40. Scientists sampled fish from one lake over a ten-year period and collected data on the concentration of mercury within the bodies of the same species of fish of various sizes. The graph given summarizes the data they collected.



The scientists who conducted the study concluded that mercury levels are higher in older fish.

a. How does the data support this conclusion?

b. Concisely explain why the older fish most likely have a higher concentration of mercury in their bodies than the younger fish.

c. Identify one experimental control used in the study. Explain the importance of this control.

Effect on Biotic Factors

In your study of ecosystems—and maybe even during a field study—you may have measured temperature, moisture content of soil, amount of sunlight, soil pH, and other **abiotic factors**. The pH of soil within an ecosystem can determine the type of plants that will grow. In turn, the types of plants present can determine the types of animals that exist within the community. Changes to the abiotic factors, especially those brought about by acid deposition, have an impact on the **biotic factors** within an ecosystem.

Recall that soil bacteria can be directly affected by acid deposition or indirectly affected by changes to the concentration of metal ions due to leaching. Besides affecting a plant's ability to produce chlorophyl, causing chlorosis, acids that directly contact plants damage the protective waxy coating on leaves. The loss of this coating permits further damage to the leaf, either by additional acid or by disease.

Aquatic organisms also demonstrate sensitivity to changes in pH. These changes are summarized in the "Sensitivity of Aquatic Organisms to pH" handout on the Science 30 Textbook CD. Because ecosystems involve complex interactions between many organisms, any change that impacts the health and survival of one organism affects the **biodiversity** of the whole ecosystem. How would you use the information in this table if you were asked to investigate whether acid deposition was affecting the area where you live? In the next investigation you will look at some locations where acid deposition has occurred and read about the effects.

- **abiotic factor:** a physical, non-living part of the environment
- **biotic factor:** a living organism in the environment
- **biodiversity:** the variety of life in all its forms, including the genetic diversity and numbers and types of organisms within an ecosystem

Utilizing Technology

Effects of Acid Deposition on Ecosystems

Purpose

You will examine information describing the effects of acid deposition on ecosystems in eastern Canada.

Science Skills

✓ Analyzing and Interpreting

Procedure

The information for this activity is located on the Science 30 Textbook CD. Obtain the document "Case Study: Eastern Canada." Read the case study; and use the information, along with what you have learned in this lesson, to answer questions 1 to 3.

Analysis

1. Are the changes to the environment in eastern Canada the result of acid deposition only? Identify any other sources that may have contributed to these effects.
2. Describe the type of data used in the material you read. Was adequate information provided regarding the effects acid deposition had on these ecosystems?
3. Evaluate the descriptions provided about the changes to the environment in eastern Canada. Are the descriptions and claims consistent with what you learned about the effects of acid deposition? Identify any similarities.

Try This Activity

Assessing Factors Involved in Acid Deposition in Alberta

Background Information

Science Skills

✓ Performing and Recording
✓ Analyzing and Interpreting

Throughout this chapter you examined activities that produce emissions related to acid deposition. The major processes that produce emissions of $SO_2(g)$ and $NO_x(g)$ in Alberta include

- the production of electricity by the combustion of coal, natural gas, or biomass
- upstream petroleum and gas production, including the processes of exploration, extracting, and processing (refining) petroleum and natural gas such as
  - sour gas flaring
  - sweetening or removal of sulfur from sour natural gas
  - removal of sulfur from crude oil
- oil sands (tar sands) production
- transportation
- use of fossil fuels as a heat source in homes or in industry (considered as stationary sources)

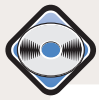
You also discovered that wind and quantity of precipitation can be major factors in determining where deposition of acidic particles or solutions will occur. In addition, you studied how the role that soil components, including calcium carbonate from limestone, can have in neutralizing acids. You also saw how acid deposition affects abiotic and biotic components of the environment and how this may impact the balance that exists within ecosystems.

With what you know about acid deposition, it is logical to wonder about Alberta's situation.

Purpose

You will research emissions related to acid deposition to obtain a clearer picture of the impact of acid deposition.

Procedure



Obtain the following handouts from the Science 30 Textbook CD.

- "Map of Alberta"
- "Canadian and US Crude Oil Pipelines and Refineries"
- "Gas Flaring and Venting in Alberta"
- "All Generating Stations by Fuel Used (1997)"
- "Sour Gas Facilities in Alberta"

Note: Zooming in on this data on your computer monitor will provide a clear view of this information.

step 1: Consult with your teacher regarding the magnitude of the area for which you are required to collect information. Is it only for your local area? province? country?

step 2: Gather information (from this textbook, the Internet, or other materials) about the following topics:

- potential of soils to reduce effects of or neutralize acid deposition
- direction of prevailing winds
- locations of electrical power generation facilities
- locations of gas wells, flares, and sour gas processing facilities
- locations of oil wells, flaring, and oil refining
- locations of tar sands (oil sands) processing
- amount of precipitation, both as rain and as snow
- pH of rainfall
- locations of major bodies of water (including rivers and lakes)

step 3: On a map of Alberta, record in an organized manner the information you collected. If codes, colours, or symbols are used, be sure to include a legend.

Analysis

Use the information on your map to identify locations in Alberta where you either

(1) consider acid deposition to currently be a problem

(2) predict acid deposition will be a problem in the future

Justify your answer.

1.3 Summary

In this lesson you learned about the complexity of the environment by studying the effect acid deposition has on soil and on the living components of ecosystems. You were introduced to the effects weather patterns (e.g., prevailing winds and precipitation) have on the transfer and deposition of acidic substances. You examined the chemical interactions between substances in the soil and hydronium ions and how these interactions can result in buffering or in leaching of metal ions. Leaching metals can be a problem associated with acid deposition. Leaching may result in the loss of nutrients from soil or an increase in the concentration in either the soil or water of certain metals that can be toxic. Mercury is an example of one metal that may biomagnify within a food chain when leached from soil. You then looked at examples from eastern Canada where acid deposition has occurred. Finally, you were asked to analyze a number of factors and apply your understanding to the situation in Alberta. In the next lesson you will examine the processes used to monitor and study acid deposition.

1.3 Questions

Knowledge

1. Define the following terms.

a. jet stream **b.** alkaline **c.** minerals

d. buffering **e.** buffering capacity **f.** biogeochemical cycles

g. leaching **h.** biomagnification **i.** biodiversity

2. State the type of relationship that exists between the concentration of sulfur dioxide, $SO_2(g)$, in the atmosphere and the pH of rain.

3. **a.** Name the type of rock that has a high buffering capacity.

b. Identify the chemical compound present in the rock type identified in question 3.a.

c. Write the chemical equation between the hydronium ions and the chemical substance identified in question 3.b.

4. List factors that contributed to the occurrence of acid deposition in eastern Canada.

5. Is acid deposition entirely the result of human activity? Support your answer.

Applying Concepts

6. At the start of this lesson you were asked to develop a hypothesis describing a relationship between the presence of emissions in the environment and their effects.

a. State a hypothesis that describes a relationship between the presence of emissions in the environment and their effects.

b. List experiments you need to conduct to test and support your hypothesis.

c. The people within a community who are closely connected to the local surroundings are often the first to notice environmental change. Identify a societal group you can consult with to determine whether they have noticed environmental changes.

d. Which type of information will you collect from the sources identified in question 6.c.? Explain how this information would help you understand the relationship between emissions and their effects on the environment.

7. Use your knowledge of soil pH to explain how it is possible for soil to be rich in nutrients but unable to support good plant growth.

8. In a study of soil exposed to acid rain, measurements of calcium ions and aluminium ions were taken at regular intervals. Ratios of the concentrations of calcium ions to aluminium ions are shown in the following table.

Soil Sample	Ratio $[Ca^{2+}] : [Al^{3+}]$	Comments
1 (pre-acidification)	1 : 1	concentrations of calcium ions and aluminium ions similar to control soil samples
2 (early stages of acidification)	2 : 1	signs of stress observed in some plant species
3 (late stages of acidification)	0.2 : 1	extreme stress observed in many plant species

a. Explain why the level of calcium ions present in soil changed.

b. It was hypothesized that the concentration of aluminium ions in soil would increase as the soil became acidified. Explain whether the ratios listed in the table support this statement.

9. Aluminium is often present in the soil as aluminium hydroxide, $Al(OH)_3(s)$.

a. Write the balanced chemical equation that occurs between hydroxide ions in the soil and hydronium ions in acid rain.

b. Explain how the reaction of hydroxide ions with hydronium ions could bring about the leaching of aluminium ions into stream and lake water.

10. A study investigating biomagnification sampled the different tissues of fish, seals, and polar bears in an arctic food chain.

Tissue Sample	Concentration of Mercury (μg/g body mass)		
	Fish	Seal	Polar Bear
muscle	0.079	0.25	0.07
liver	0.080	3.0	15
kidney	0.080	1.2	15

a. Explain how the data demonstrates that mercury biomagnifies within a food chain.

b. Hypothesize why differences may exist in the concentration of mercury in different tissues in some organisms.

c. Explain how the results of this study may impact the work of other scientists.

11. The accumulation of acid deposition in soil and water can result in a lowering of pH, which causes a decrease in the number of bacteria that decompose plant and animal matter in an ecosystem. Explain how a decrease in the number of bacteria that decompose plant and animal matter would negatively affect an ecosystem.